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REDWING

PACIFIC PROVING GROUNDS ASI A

May - July 1956

Project 2.52

NEUTRON-INDUCED SOIL RADIOACTIVITY (U)

Issuance Date: December 10, 1959

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OPERATION REDWING — PROJECT 2.52 (U)

NEUTRON-INDUCED SOIL RADIOACTIVITY, (U)

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by Maynard Cowan, Jr.

Sandia Corporation
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FOREWORD

This report presents the final results of one of the projects participating in the military-effect programs of Operation Redwing. Overall information about this and the other military-effect projects can be obtained from WT–1344, the "Summary Report of the Commander, Task Unit 3." This technical summary includes: (1) tables listing each detonation with its yield, type, environment, meteorological conditions, etc.; (2) maps showing shot locations; (3) discussion of results by programs; (4) summaries of objectives, procedures, results, etc., for all projects; and (5) a listing of project reports for the military-effect programs.

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ABSTRACT

Soil samples were exposed to neutron radiation from Shot Cherokee to help establish
the importance of neutron-induced residual gamma radiation from a large-yield ther-
monuclear air burst. After exposure and recovery, the samples had no detectable
activity because the slant range to the nearest sample was nearly 3.5 miles, due to
an error in bomb drop. After this failure, an experiment was designed in the field
for Shot Yuma in order that induced-activity data could be obtained for a soil other
than Nevada Test Site (NTS) soil. Samples of sodium, manganese, and coral sand
from Site Sally were exposed above and below the surface at a slant range of 120 yards.
At this same station, gamma dose rates were measured and neutron detectors were
exposed by Project 2.51.

The full-field gamma radiation measured was due to a combination of fission-product
and neutron-induced activities, the only important induced activity being due to $Na_{11}^{23}(n,\gamma)$ to Na^{24}. At 1.1, 3.4, and 10.9 hours after zero time, neutron-induced gamma radiation ac-
counted for 1.2, 1.1, and 0.8 r/hr of the measured 6.0, 2.2, and 1.2 r/hr. These values
were found to be within 50 percent of neutron-induced dose rates predicted by the method
of Reference 1.

CONTENTS

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INTRODUCTION

1.1 OBJECTIVE

This experiment was designed to provide data to aid the formulation of a method for predicting the gamma-radiation field caused by air bursts. Specific objectives were to measure the induced activity from a large-yield, thermonuclear air burst and to exploit the opportunity offered for an investigation of activity induced in some soil other than the soil of Nevada Test Site (NTS). When a bomb-drop error prevented any data being obtained on Shot Cherokee, an additional experiment was set up on Shot Yuma to obtain some data applicable to the second specific objective.

1.2 REASONS FOR EXPERIMENT

Certain military uses of nuclear weapons demand a minimum of residual contamination. For example, it might be desirable to exploit the first shock of a nuclear burst by having friendly troops occupy or pass through the ground-zero area soon after the detonation. Although for practical purposes there is no local fallout from an air burst, a considerable area around ground zero can be rendered radioactive by neutron bombardment, and the gamma-radiation field thus produced can prove dangerous to persons entering it hours later. The intensity and decay of such a gamma-radiation field will depend on the kind of weapon, its yield and height of burst, and on the elements which make up the soil around ground zero. This experiment was expected to provide data for the evaluation of the military significance of neutron-induced activity.

1.3 BACKGROUND

Tests at the NTS have led to empirical methods for predicting neutron-induced dose rates from air bursts in the kiloton range over Nevada soil (References 1 and 2). These methods attempt to predict 1-hour dose rates over any area within the test site. However, since no attempts have been made to correlate dose rates and decay rates with the chemical composition of a variety of soils, the methods are valueless for any but Nevada-type soil. Furthermore, since in Nevada soil the amount of sodium, the most important contributor to induced activity, varies from area to area within the test site by as much as a factor of four, the accuracy of such methods is severely limited even for NTS.

A method for the prediction of induced activity which does account for chemical differences in soils has been developed by Canu and Dolan (Reference 3). Before predictions are made for a given soil, the amounts of over twenty elements in the soil must be determined. The gold-neutron flux expected is also used to help establish intensities at times of interest. However, this method has the following important shortcomings:

1. No allowance is made for the moderation of high-energy neutrons into the low-

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energy region. For most weapons and soils, this is the most important source of thermal neutrons which cause most of the induced activity. Properties of soil elements pertaining to this most important effect are ignored. Elements are weighted strictly on the basis of the relative number of thermal neutrons they absorb.

2. No allowance is made for the distribution of activity with depth in soil nor for properties of the soil constituents which influence this distribution.

3. The neutron spectrum is assumed to be invariant with slant range and weapon type.

In other respects, too, this method was developed from unrealistic assumptions. From a practical standpoint, however, the shortcomings above are the most important.

1.4 PREDICTION METHOD

A prediction method (Reference 4) has been developed which requires the following:

1. Soil Data. Soil density (gm/cm^3) and percentage by weight of Na, Mn, Al.

2. Neutron Data. Gold neutrons versus slant range and total number of 14-Mev neutrons per kt produced external to the case.

1.4.1 Basic Theory. Briefly, the theory for this method is developed as follows:

N_0 = time-integrated neutron density from an isotropic source in air through a thin layer of soil at the surface

N = time-integrated neutron density through a thin layer at depth X below the surface

Then,

$$N = f(X) N_0 \tag{1.1}$$

where f(X) depends on the soil and the incident neutron spectrum.

The number of neutrons absorbed by a particular isotope in a layer of unit area dx thick at depth X is

$$dm_i = N_0 \rho_i k_i(X) f(X) dx \tag{1.2}$$

where ρ_i is the number of atoms per unit volume of an isotope (considered constant with depth), and $k_i(X)$ depends on the capture cross section for this isotope and the neutron spectrum at X.

The contribution made by the radioactive daughter of this isotope to the residual gamma-radiation field above the surface is

$$dI_i = g_i(X) dm_i e^{-\lambda_i t} \tag{1.3}$$

The gamma-ray attenuation function, $g_i(X)$, depends primarily on the density of the soil and the energy of gamma radiations from the radioactive daughter. When there is no gamma-emitting daughter, $g_i(X) = 0$.

Radiation of the soil by neutrons is considered to be instantaneous at t = 0. No daughter-daughter gamma-emitting products are considered since the neutron-induced

radioisotopes of interest give rise to stable daughters.

From Equations 1.2 and 1.3

$$I_i = N_0 \rho_i e^{-\lambda_i t} \int g_i(X) f_i(X) k_i(X) \, dx \tag{1.4}$$

For a particular soil and incident neutron spectrum, the integral is a constant, and

$$I_i = N_0 K_i \rho_i e^{-\lambda_i t} \tag{1.5}$$

where K_i is a constant. When a number of gamma-emitting radioisotopes are formed, the dose rate above the surface is given by

$$I = N_0 \left[\rho_1 K_1 e^{-\lambda_1 t} + \rho_2 K_2 e^{-\lambda_2 t} + \ldots + \rho_n K_n e^{-\lambda_n t} \right] \tag{1.6}$$

This equation describes the dose rate at any time only for a given soil and incident neutron spectrum. Different K values may be expected for each different soil and spectrum combination.

1.4.2 Neutron Spectra. Although neutron spectra vary both with slant range and weapon type, spectra from all weapons nevertheless seem to approach the same equilibrium spectrum as slant range increases, so that for slant ranges greater than 900 yards there is invariance with slant range and weapon type.

Before this equilibrium spectrum is established, the spectrum is always softer (relatively more gold neutrons). In general, both the degree of softness and the slant range necessary to establish the equilibrium condition are greater for weapons having the largest amounts of high explosive. In this method, corrections are made for changes in spectrum when they occur.

1.4.3 Soil Differences. To establish those characteristics of soils which must be considered to give a reasonable degree of prediction accuracy, extremes in the amounts of important soil elements were considered. The influence of each element on the overall moderating or slowing-down power of soil was assessed, as was the importance of each element for absorption of thermal neutrons. Gold neutron measurements versus depth in Nevada soil served to evaluate the importance of build-up caused by moderation, so that relative dose rates could be calculated for extreme cases.

The moderating power of a soil is determined by its amount of hydrogen, the main source of hydrogen being the moisture content of soil. However, a compensating effect causes dose rates measured above the surface of soil to be fairly insensitive to the actual amount of hydrogen (over the expected range of hydrogen abundance or moisture content). When the hydrogen content is high, build-up of low-energy neutrons occurs closer to the surface, but the diffusion length (L) of thermal neutrons thus formed is correspondingly shorter, a factor which causes faster decay with depth. For a low hydrogen content, build-up near the surface is less; but the decay of thermal neutrons with depth is also less (larger L). However, activity produced near the surface must be considered more important than like amounts at greater depths, since emitted gamma rays must penetrate the soil overburden. Thus, without calculation, it is not obvious to what extent such a compensating effect operates.

Figure 1.1, reproduced from Reference 4, shows the extremes expected in relative dose rates for soils with differing amounts of hydrogen. These extremes were calcu-

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lated by choosing quantities for other elements found in soil which would maximize or minimize the value of L but would not exceed the expected range of abundance of any element. The relative standing of NTS soil is also shown in the figure. For the equilibrium spectrum, the figure shows that dose rates for soils containing equal amounts of those elements which lead to gamma emitters on (n, γ) reaction could be, at most, 30 percent higher or 56 percent lower than those at NTS.

Since neutron spectra from weapons can be softer than the equilibrium spectrum, a
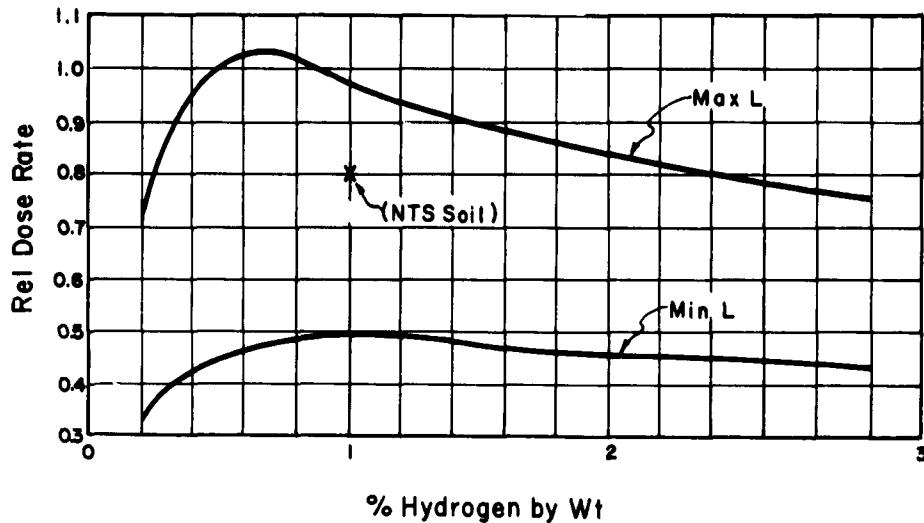
Figure 1.1 Dose rate versus hydrogen content.

similar evaluation of extremes for a 100-percent thermal neutron source was made. It was shown that dose rates for a straight thermal neutron source would be, at most, 20 percent higher or 35 percent lower than for NTS soil.

From the evaluation of these extreme situations, it was concluded that neutron-induced dose rates can be predicted with reasonable accuracy with only a knowledge of those elements which produce gamma-emitting radioisotopes. That is, for a given spectrum, one set of K's may be used in Equation 1.6 for all soils.

1.5 SUMMARY OF PREDICTION METHOD

Only three terms will be needed in Equation 1.6, one each for sodium, manganese, and aluminum. Assuming that capture cross sections for these three elements have similar behavior with neutron energy, for the equilibrium spectrum Equation 1.6 may be written:

$$I = \rho\, n_0\, K \left[(\% \text{ Na})\, e^{-\lambda_1 t} + 24.7\ (\% \text{ Mn})\, e^{-\lambda_2 t} + 60.3\ (\% \text{ Al})\, e^{-\lambda_3 t} \right] \quad (1.7)$$

Where: ρ = density of soil (gm/cm^3)

n_0 = gold neutron measurement or estimate ($n_0 \sim N_0$ for a given spectrum)

K = $3.93 \pm 0.15 \times 10^{-13}$ (evaluated from NTS results)

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(%) = percentage by weight of element

λ_1 = 0.046/hr

λ_2 = 0.266/hr

λ_3 = 18/hr

The numbers 24.7 and 60.3 in the equation give added weight to the manganese and alu-
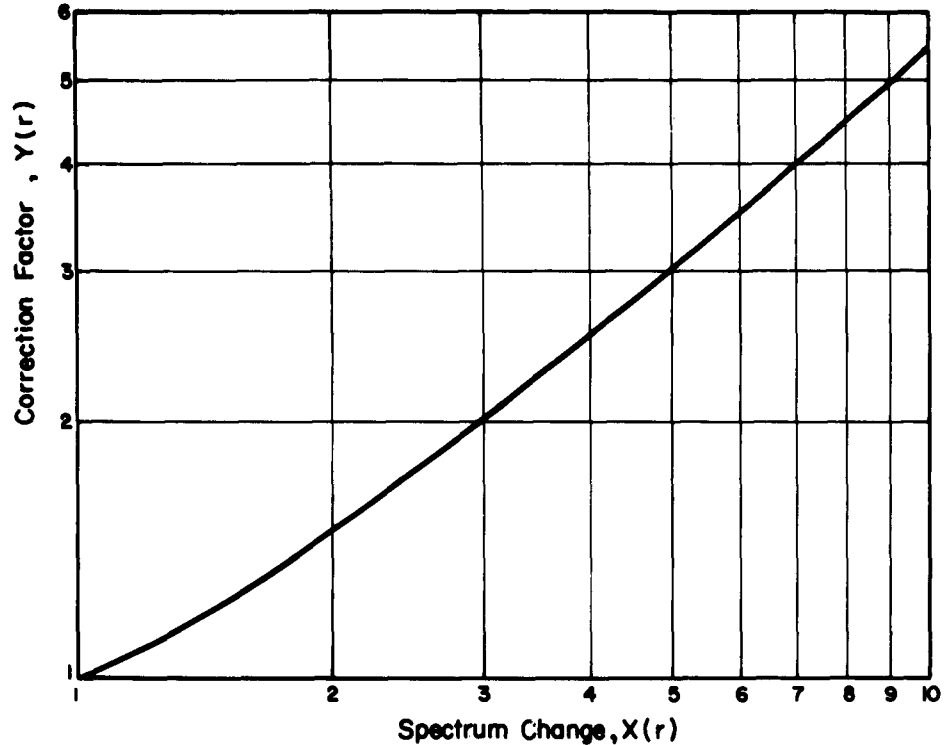
Figure 1.2 Corrections for variations in neutron spectrum.

minum relative to sodium on the basis of capture cross section, half-lives, atomic weights, and gamma energies per disintegration.

Then, for some other slant range, r,

$$I_r = Y(r) I_{r_1} \frac{r_1}{r} e^{(r_1-r)/200} \tag{1.8}$$

where $Y(r) \geq 1$. The factor $Y(r)$ accounts for the effect of a spectrum which is softer than the equilibrium spectrum. $Y(r)$ is a function of $X(r)$ where

$$X(r) = \frac{(r\,n_0)\,r}{(r_1 n_0)r_1} e^{(r-r_1)/200} \tag{1.9}$$

The factor $X(r)$ is the ratio of the surface thermal-neutron density actually measured or predicted for slant range, r, to that which would exist at r if the equilibrium spectrum obtained between r and r_1. Because of the importance of build-up of thermal neutrons below the surface,

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$$X(r) \geq Y(r)$$

Figure 1.2 is a plot of $Y(r)$ versus $X(r)$ calculated by assuming that the relative importance of build-up is inversely proportional to $X(r)$. That is,

$$X(r) q(x)_r = q(x)_{r_1}$$

where $q(x)_{r_1}$ is the build-up for equilibrium spectrum. The correction factor shown is for a low H content and is therefore conservative. That is, errors will occur from overestimating, not underestimating, dose rates. For modern weapons with small amounts of high explosive, $X(r)$ will probably never exceed three.

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Chapter 2
PROCEDURE

Shot Cherokee, a 3.5-Mt air burst to be detonated 5,000 feet over Site Charlie, was chosen to investigate induced activity from large-yield, thermonuclear weapons. The ten types of soil used on Shot 5 of Operation Teapot (Reference 4) were exposed to the neutron flux from Shot Cherokee near each of three neutron-detector stations of Project 2.51, located at 80, 1,250, and 2,500 feet from the intended ground zero. Also exposed at each station were a sample of coral sand taken from the island and one sample each of sodium and manganese in the form of salt (NaCl) and manganese dioxide (MnO_2). The latter were included so that a long delay in sample recovery would not result in a loss of all data.

All samples were exposed in watertight steel containers attached by $5/16$-inch aircraft cable to large eyebolts set in concrete. The soil sample container was covered with coral soil so that the neutron spectrum incident on the soil samples would be typical of that 1 to 4 inches below the surface. This was thought to be the depth range for maximum thermal neutron density.

Recovery was made at H+6 hours by helicopter, and all samples were taken to Site Elmer where the soil samples were measured with a gamma-ray spectrometer. Dose-rate measurements were made at each of the three stations by the recovery crew.

When the results expected from Shot Cherokee were not obtained, Shot Yuma, a 0.19-kt burst on a 200-foot tower at Site Sally, was chosen to investigate the effect of neutron-induced gamma-radiation fields on a soil different from Nevada soil. Samples of NaCl, MnO_2, and coral soil from the island were exposed at 100 yards ground range near Station 253.08 of Project 2.51. Six samples were exposed, each of the three materials in a steel container about 3 inches above the ground and each in a thin aluminum container about 1 inch below the soil surface. The activity of the recovered samples was measured in a gamma spectrometer, and the resulting spectra were determined as functions of time for all samples. The dose rate near Station 253.08 was measured by a Rad-Safe helicopter hovering at 25 feet at H+1.1 hours and by ground crews at H+3.4 and H+10.9 hours.

The gamma spectrometer used was the 20-channel differential pulse-height analyzer manufactured by the Atomic Instrument Company, equipped with their Model 810 scintillator head, which contained a 2-inch diameter NaI well crystal. The primary calibration was made with chemically pure NaCl and MnO_2 activated in the Los Alamos Laboratory's water-boiler reactor. Properties of the sample holder were minimized by substitution; the same kind were used to obtain the final data and for the calibration runs. Calibrations were made with the pure materials and with a mixture of pure materials and coral soil. Calibrations involved about 2,000 counts per channel; final data runs, about 1,000. It should be noted that the spectrometer required too much maintenance to be entirely satisfactory.

Chapter 3

RESULTS

Because of a bombing error, the estimated slant range from Shot Cherokee burst point to the nearest station on Site Charlie was 3.5 miles. There was no detectable activity in any of the samples when measured at H+7 hours. Gamma dose rates at Site Charlie were background only.

Chemical analysis of two Site Charlie soil samples indicated their sodium content to be 0.11 and 0.16 percent by weight, while one sample from Site Sally indicated 0.15-percent sodium by weight. In Table 3.1, these values are compared to several values determined for NTS soils.

The two samples of coral soil exposed to Shot Yuma showed only Na^{24} activity when first measured at H+5 hours. In Table 3.2, a summary of data on activity induced in the six samples is given. Activities are given in dis/min-gm of sample, extrapolated to zero time. The kinds of activity present were identified by the energies and half lives of gamma radiation emitted. The probable error in these activation data is ± 5 percent. Figures 3.1 through 3.3 show sample records for coral soil, NaCl and MnO_2.

Dose rates measured after Shot Yuma near Station 253.08 are shown in Table 3.3. Gold neutron measurements made on Shot ma are summarized in Figure 3.4 (Reference 5).

TABLE 3.1 SODIUM AND MANGANESE CONTENTS OF VARIOUS TEST SITE SOILS

Location	Sodium	Manganese
	pct by weight	pct by weight
Center, Site Charlie	0.16	—
Shore, Site Charlie	0.11	—
Station 253.09, Site Sally	0.15	—
Area 1, NTS	1.25	0.158
Area 2, NTS	0.43	0.027
Area 3, NTS	1.60	0.024
Area 4, NTS	0.95	0.032
Area 7, NTS	1.84	0.045
Area 7, NTS	1.81	0.047
Area 7, NTS	1.33	0.030
Area F, NTS	0.62	0.023

TABLE 3.2 SAMPLE ACTIVATION DATA, SHOT YUMA

Sample	Kind of Activity	Above Surface	Below Surface	Ratio Below/Above
		dis/min-gm	dis/min-gm	
Coral	Na^{24}	5.09×10^5	9.81×10^5	1.93
NaCl	Na^{24}	5.73×10^7	1.34×10^8	2.34
MnO_2	Mn^{56}	5.32×10^9	1.18×10^{10}	2.22

TABLE 3.3 DOSE RATES NEAR STATION 253.08, SHOT YUMA

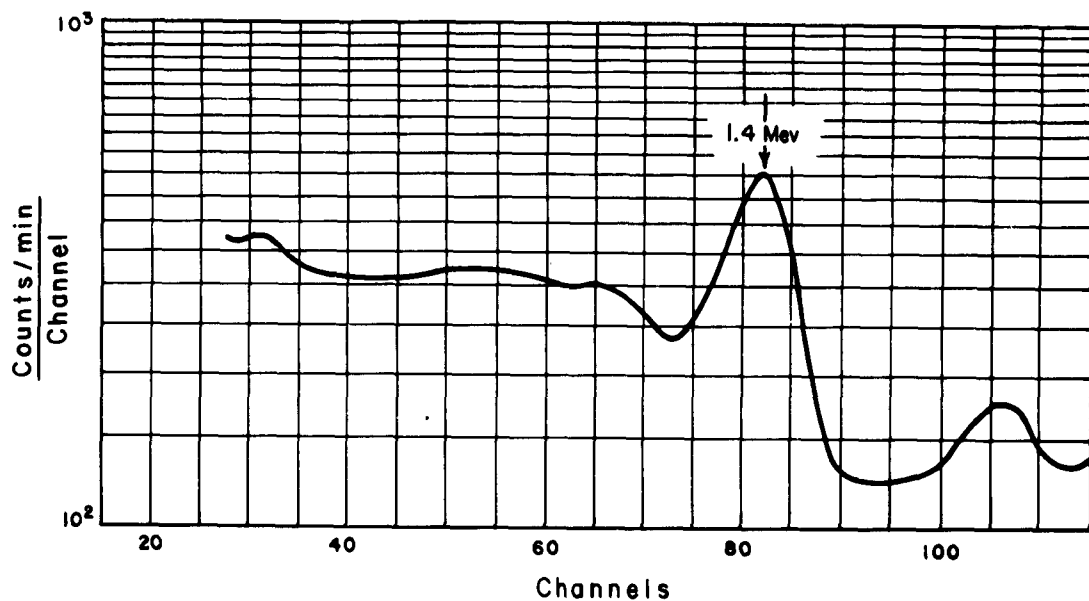| Time	Dose Rate 3 ft Above Surface	Method
	r/hr	
H + 1.1 hr	6	Inferred from 25-ft helicopter measurement
H + 3.4 hr	2.2	Ground monitor reading
H + 10.9 hr	1.2	Ground monitor reading using AN/PDR-T1B

Figure 3.1 Sample of coral soil data.
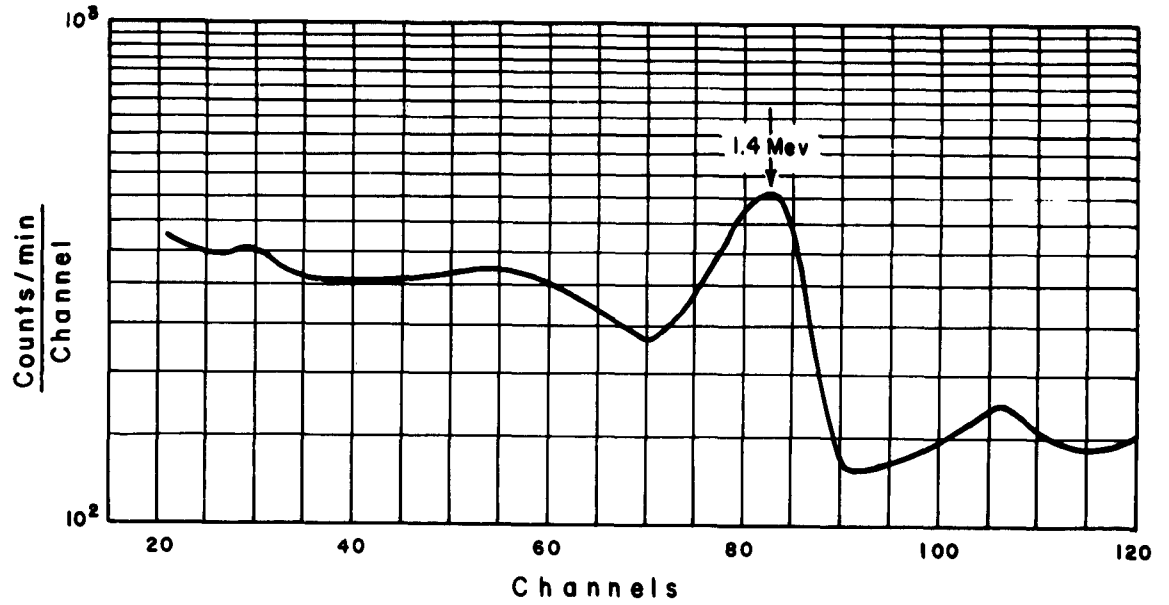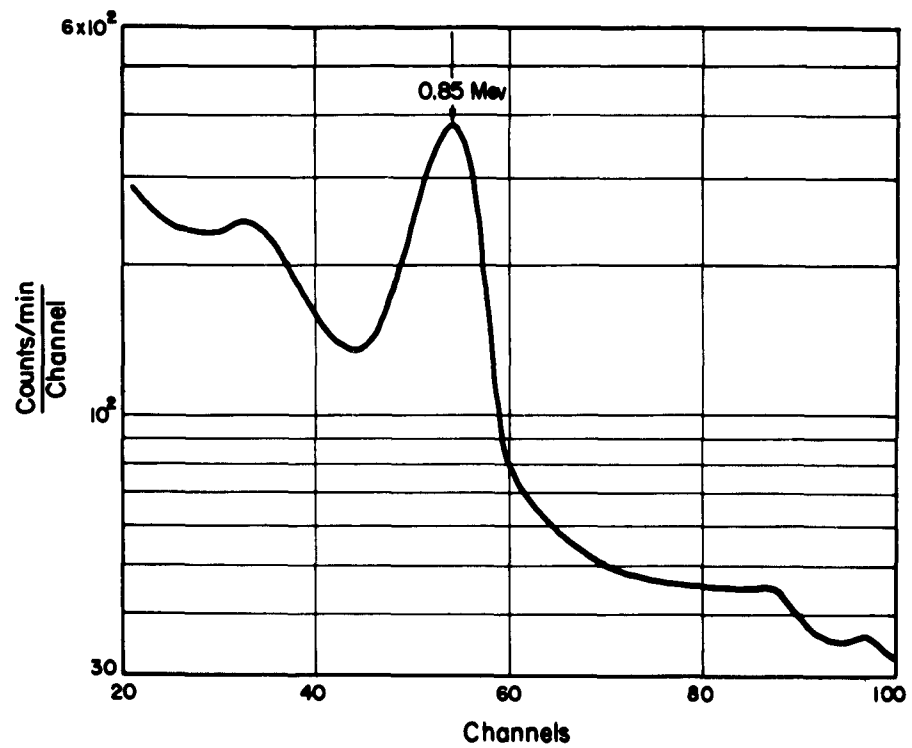
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Figure 3.2 Sample of NaCl data.

Figure 3.3 Sample of MnO$_2$ data.
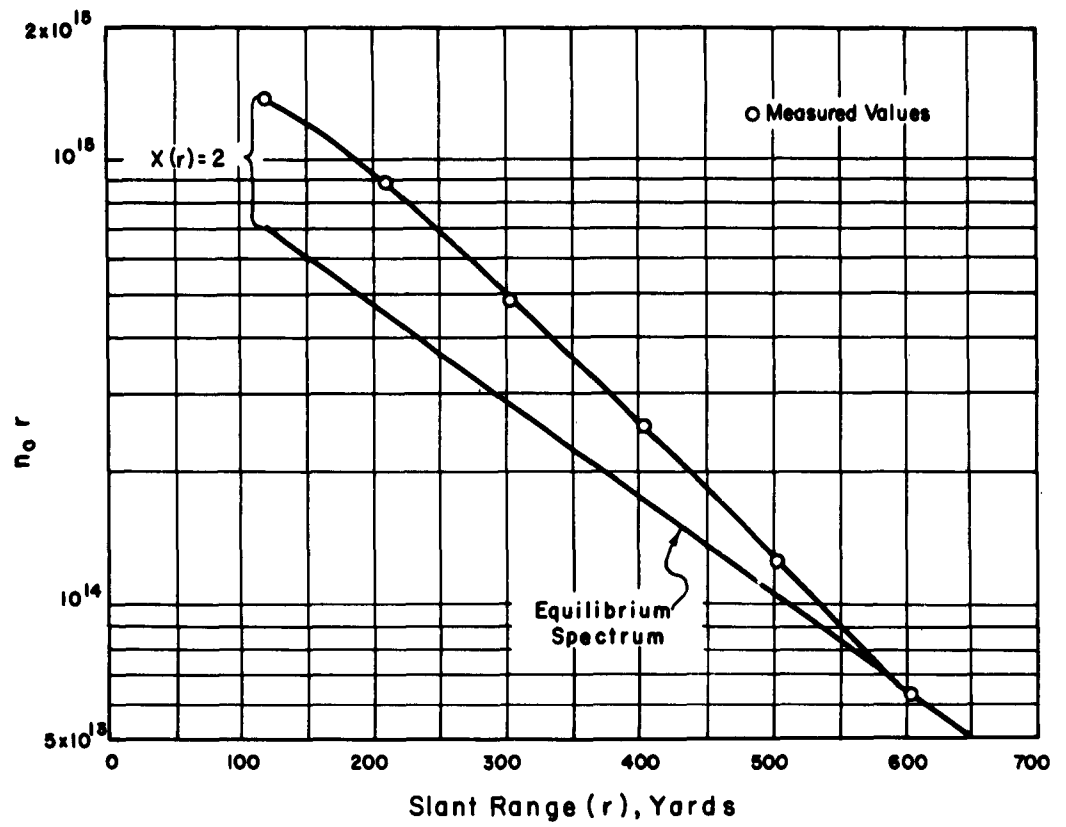
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Figure 3.4 Shot Yuma gold neutrons versus slant range.

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Chapter 4
DISCUSSION and CONCLUSIONS

4.1 DISCUSSION

By comparing Na^{24} activities in the coral and NaCl samples (Table 3.2), the percent by weight of Na in coral was determined to be 0.31 ± 0.03. This is twice the amount determined by chemical analysis (Table 3.1). The Na^{24} activity must be assumed to be due to $Na^{23}(n, \gamma) Na^{24}$, since neither coral nor NaCl contains enough Al or Mg to produce competitive amounts of Na^{24} by (n, α) or (n, p).

For such small amounts of sodium, it is believed that the comparative activation method is the more accurate. This could imply a consistent chemical error, because two other samples of coral from Site Charlie (Namu Island, Bikini) show 0.16 percent and 0.11 percent by chemical analysis. It is also possible that the sodium content in coral may vary by as much as a factor of two within a small area.

From Equations 1.7, 1.8, and 1.9 and the neutron measurements of Project 2.51, dose rates were calculated at 1.1, 3.4, and 10.9 hours after zero time. Results are shown in Table 4.1.

The greatest slant range at which a gold neutron measurement was made for Shot Yuma was 604 yards. In order to make a dose rate calculation by the method of Reference 4, it must be assumed that the equilibrium spectrum was established at 604 yards slant range. On the basis of experience with devices containing small amounts of high explosive, this assumption is reasonable. The dose rate was calculated (Equation 1.7) for 604 yards slant range with $n_0 = 1.05 \times 10^{11}$ and $\rho = 1.6$ gm/cm^3. For dry coral, $\rho = 1.3$, while for coral completely saturated with water, $\rho = 1.8$ gm/cm^3. The value 1.6 is an estimate of conditions at shot time. $X(r)$ was calculated (Equation 1.9) to be 2 for 120 yards slant range; hence $Y(r) = 1.5$ from Figure 1.2. Equation 1.8 was then used to calculate dose rate at 120 yards slant range. As seen in Figure 4.1, measured dose rates do not show the decay with time characteristic of Na^{24}. Since Na^{24} was the only important induced activity found in coral, it was concluded that measured values were the result of superimposition of the 15-hour half-life Na^{24} and $t^{-1.2}$ fission product activities. A least-squares fit applied to the dose rate versus time data implied fission product contributions of 4.7, 1.2, and 0.3 r/hr, and Na^{24} contributions of 1.2, 1.1, and 0.8 r/hr at H + 1.1, 3.4, and 10.9 hours (Figure 4.1). This analysis seems consistent with the measured values.

When the amount of sodium used for coral is that determined by the comparative activation method, calculated values range from 1.33 to 1.25 times the values inferred from field measurements. When the chemically determined value for sodium is used, inferred dose rates are 1.50 to 1.6 times the calculated dose rates. This suggests that the correct average sodium content for coral lies somewhere between 0.15 and 0.31 percent. However, errors implicit in the prediction method and in field measurements of dose rates do not allow confidence in this deduction.

Measured dose rates are probably subject to ± 25-percent error, and the estimated probable error in prediction method is ± 30 percent. Assuming that these are the major sources of error, agreement between calculated and measured dose rates is subject to probable error of ± 40 percent.

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TABLE 4.1 COMPARISON OF CALCULATED AND MEASURED DOSE RATES

Time After Zero Time	Measured Dose Rate	Contribution of Neutron-Induced Radiation to Measured Dose Rate	Calculated Dose Rate 0.31 pct Na	Calculated Dose Rate 0.15 pct Na
hour	r/hr	r/hr	r/hr	r/hr
1.1	6.0	1.2	1.6	0.8
3.4	2.2	1.1	1.4	0.7
10.9	1.2	0.8	1.0	0.5
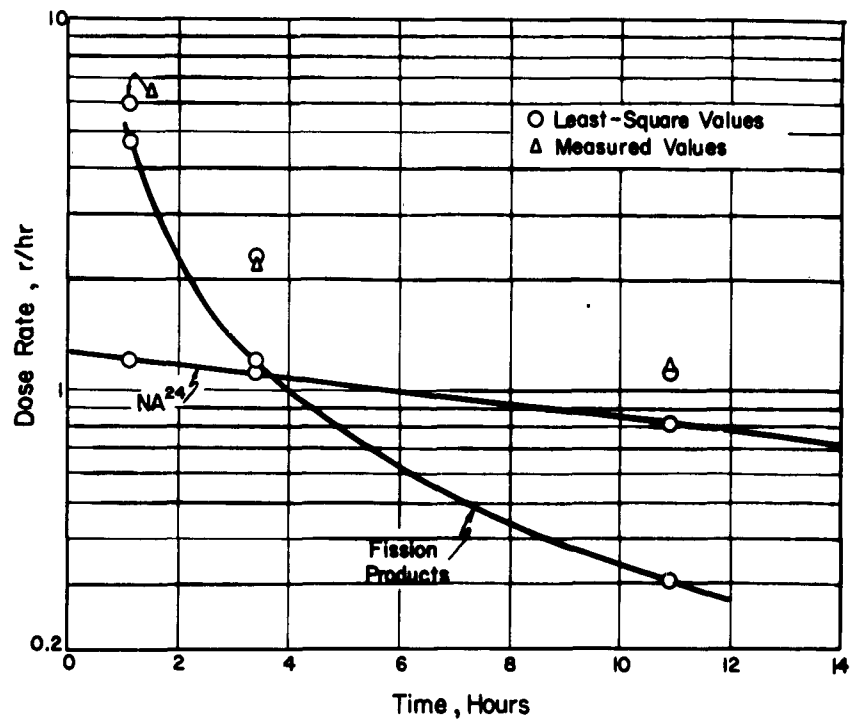
Figure 4.1 Least-square values compared to measurements.

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The build-up of thermal neutrons with depth in soil is indicated by the relatively high activity of buried samples; however, activity differences between buried and unburied samples are greater than expected. The samples which were exposed above the surface may have been shielded somewhat by the sandbags which were used by Project 2.51 to hold their detectors off the ground. Although the samples were between the sandbags and the device, shielding could still be significant because low-energy neutron flux is nearly isotropic.

4.2 CONCLUSIONS

The difference between the effects of pure fission and fission-fusion neutron spectra on induced activity in soil was not measured, since the soil samples on Shot Cherokee were not activated. However, a method for predicting neutron-induced gamma-radiation intensities (Reference 4) was tested for coral soil on Shot Yuma. Predicted values were within ± 50 percent of induced dose rates inferred from field measurements.

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37 The Superintendent, U.S. Military Academy, West Point, N.Y. ATTN: Prof. of Ordnance
38 Commandant, The Quartermaster School, U.S. Army, Ft. Lee, Va. ATTN: Chief, QM Library
39 Commandant, U.S. Army Ordnance School, Aberdeen Proving Ground, Md.
40 Commandant, U.S. Army Ordnance and Guided Missile School, Redstone Arsenal, Ala.
41 Commanding General, Chemical Corps Training Comd., Ft. McClellan, Ala.
42 Commandant, USA Signal School, Ft. Monmouth, N.J.
43 Commandant, USA Transport School, Ft. Eustis, Va. ATTN: Security and Info. Off.
44 Commanding General, The Engineer Center, Ft. Belvoir, Va. ATTN: Asst. Cmdt, Engr. School
45 Commanding General, Army Medical Service School, Brooke Army Medical Center, Ft. Sam Houston, Tex.
46 Director, Armed Forces Institute of Pathology, Walter Reed Army Med. Center, 625 16th St., NW, Washington 25, D.C.

47 Commanding Officer, Army Medical Research Lab., Ft. Knox, Ky.
48 Commandant, Walter Reed Army Inst. of Res., Walter Reed Army Medical Center, Washington 25, D.C.
49- 50 Commanding General, Qm R&D Comd., QM R&D Cntr., Natick, Mass. ATTN: CBR Liaison Officer
51- 52 Commanding General, U.S. Army Chemical Corps, Research and Development Comd., Washington 25, D.C.
53- 54 Commanding Officer, Chemical Warfare Lab., Army Chemical Center, Md. ATTN: Tech. Library
55 Commanding General, Engineer Research and Dev. Lab., Ft. Belvoir, Va. ATTN: Chief, Tech. Support Branch
56 Director, Waterways Experiment Station, P.O. Box 631, Vicksburg, Miss. ATTN: Library
57 Commanding Officer, Office of Ordnance Research, Box CM, Duke Station, Durham, North Carolina
58 Commanding Officer, Picatinny Arsenal, Dover, N.J. ATTN: ORDBB-TK
59 Commanding Officer, Diamond Ord. Fuze Labs., Washington 25, D.C. ATTN: Chief, Nuclear Vulnerability Br. (230)
60- 61 Commanding General, Aberdeen Proving Grounds, Md. ATTN: Director, Ballistics Research Laboratory
62 Commanding General, Frankford Arsenal, Bridge and Tacony St., Philadelphia, Pa.
63- 64 Commanding General, U.S. Army Ord. Missile Command, Redstone Arsenal, Ala.
65 Commander, Army Rocket and Guided Missile Agency, Redstone Arsenal, Ala. ATTN: Tech Library
66 Commanding General, White Sands Proving Ground, Las Cruces, N. Mex. ATTN: ORDBS-OM
67 Commander, Army Ballistic Missile Agency, Redstone Arsenal, Ala. ATTN: ORDAB-HT
68 Commanding Officer, Ord. Materials Research Off., Watertown Arsenal, Watertown 72, Mass. ATTN: Dr. Foster
69 Commanding General, Ordnance Tank Automotive Command, Detroit Arsenal, Centerline, Mich. ATTN: ORDMC-RO
70 Commanding General, Ordnance Ammunition Command, Joliet, Ill.
71 Commanding Officer, USA Signal R&D Laboratory, Ft. Monmouth, N.J.
72 Commanding General, U.S. Army Electronic Proving Ground, Ft. Huachuca, Ariz. ATTN: Tech. Library
73 Commanding General, USA Combat Surveillance Agency, 1124 N. Highland St., Arlington, Va.
74 Commanding Officer, USA, Signal R&D Laboratory, Ft. Monmouth, N.J. ATTN: Tech. Doc. Ctr., Evans Area
75 Commanding Officer, USA Transportation Combat Development Group, Ft. Eustis, Va.
76 Director, Operations Research Office, Johns Hopkins University, 6935 Arlington Rd., Bethesda 14, Md.
77 Commandant, U.S. Army Chemical Corps, CBR Weapons School, Dugway Proving Ground, Dugway, Utah.
78 Commanding General, U. S. ORD Special Weapons-Ammunition Command, Dover, N.J.
79 Commander-in-Chief, U.S. Army Europe, APO 403, New York, N.Y. ATTN: Opot. Div., Weapons Br.
80 Commanding General, Southern European Task Force, APO 168, New York, N.Y. ATTN: ACofS G-3
81 Commanding General, Eighth U.S. Army, APO 301, San Francisco, Calif. ATTN: ACofS G-3
82 Commanding General, U.S. Army Alaska, APO 949, Seattle, Washington
83 Commanding General, U.S. Army Caribbean, Ft. Amador, Canal Zone. ATTN: Cml Office
84 Commander-in-Chief, U.S. Army Pacific, APO 958, San Francisco, Calif. ATTN: Ordnance Officer
85 Commanding General, USARFANT & MDPR, Ft. Brooke, Puerto Rico
86 Commanding Officer, 9th Hospital Center, APO 180, New York, N.Y. ATTN: CO, US Army Nuclear Medicine Research Detachment, Europe

NAVY ACTIVITIES

87 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-03EG
88 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-75
89 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-92202
90 Chief of Naval Personnel, D/N, Washington 25, D.C.
91- 92 Chief of Naval Research, D/N, Washington 25, D.C. ATTN: Code 811
93- 94 Chief, Bureau of Aeronautics, D/N, Washington 25, D.C.
95 Chief, Bureau of Medicine and Surgery, D/N, Washington 25, D.C. ATTN: Special Wpns. Def. Div.
96 Chief, Bureau of Ordnance, D/N, Washington 25, D.C.
97 Chief, Bureau of Ordnance, D/N, Washington 25, D.C. ATTN: S.P.
98 Chief, Bureau of Ships, D/N, Washington 25, D.C. ATTN: Code 423
99 Chief, Bureau of Yards and Docks, D/N, Washington 25, D.C. ATTN: D-440
100 Director, U.S. Naval Research Laboratory, Washington 25, D.C. ATTN: Mrs. Katherine H. Cass
101-102 Commander, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring 19, Md.
103 Director, Material Lab. (Code 900), New York Naval Shipyard, Brooklyn 1, N.Y.
104 Commanding Officer and Director, Navy Electronics Laboratory, San Diego 52, Calif.
105-108 Commanding Officer, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. ATTN: Tech. Info. Div.
109-111 Commanding Officer and Director, U.S. Naval Civil Engineering Laboratory, Port Hueneme, Calif. ATTN: Code L31
112 Superintendent, U.S. Naval Academy, Annapolis, Md.
113 Commanding Officer, U.S. Naval Schools Command, U.S. Naval Station, Treasure Island, San Francisco, Calif.
114 Superintendent, U.S. Naval Postgraduate School, Monterey, Calif.
115 Officer-in-Charge, U.S. Naval School, CEC Officers, U.S. Naval Construction Bn. Center, Port Hueneme, Calif.
116 Commanding Officer, Nuclear Weapons Training Center, Atlantic, U.S. Naval Base, Norfolk 11, Va. ATTN: Nuclear Warfare Dept.
117 Commanding Officer, Nuclear Weapons Training Center, Pacific, Naval Station, San Diego, Calif.
118 Commanding Officer, U.S. Naval Damage Control Tng. Center, Naval Base, Philadelphia 12, Pa. ATTN: ABC Defense Course
119 Commanding Officer, Air Development Squadron 5, VX-5, China Lake, Calif.
120 Commander, Officer U.S. Naval Air Development Center, Johnsville, Pa. ATTN: NAS, Librarian
121 Commanding Officer, U.S. Naval Medical Research Institute, National Naval Medical Center, Bethesda, Md.
122 Commanding Officer and Director, David W. Taylor Model Basin, Washington 7, D.C. ATTN: Library
123 Officer-in-Charge, U.S. Naval Supply Research and Development Facility, Naval Supply Center, Bayonne, N.J.
124 Commander-in-Chief, U.S. Atlantic Fleet, U.S. Naval Base, Norfolk 11, Va.
125 Commandant, U.S. Marine Corps, Washington 25, D.C. ATTN: Code A03H
126 Director, Marine Corps Landing Force, Development Center, MCS, Quantico, Va.
127 Chief, Bureau of Ships, D/N, Washington 25, D.C. ATTN: Code 372
128 Commanding Officer, U.S. Naval CIC School, U.S. Naval Air Station, Glynco, Brunswick, Ga.
129 Chief of Naval Operations, Department of the Navy, Washington 25, D.C. ATTN: OP-25
130 Commander-in-Chief, U.S. Pacific Fleet, Fleet Post Office, San Francisco, Calif.

AIR FORCE ACTIVITIES

131 Assistant for Atomic Energy, HQ, USAF, Washington 25, D.C. ATTN: DCS/O
132 Deputy Chief of Staff, Operations, HQ. USAF, Washington 25, D.C. ATTN: AFOOP
133 Hq. USAF, ATTN: Operations Analysis Office, Office, Vice Chief of Staff, Washington 25, D.C.
134 Director of Civil Engineering, HQ. USAF, Washington 25, D.C. ATTN: AFOCE

135-136 Assistant Chief of Staff, Intelligence, HQ. USAF, Washington 25, D.C. ATTN: AFCIN-3B
137 Director of Research and Development, DCS/D, HQ. USAF, Washington 25, D.C. ATTN: Guidance and Weapons Div.
138 The Surgeon General, HQ. USAF, Washington 25, D.C. ATTN: Bio.-Def. Pre. Med. Division
139 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Doc. Security Branch
140 Commander, Air Defense Command, Ent AFB, Colorado. ATTN: Assistant for Atomic Energy, ADLDC-A
141 Commander, Hq. Air Research and Development Command, Andrews AFB, Washington 25, D.C. ATTN: RDRWA
142 Commander, Air Force Ballistic Missile Div. HQ. ARDC, Air Force Unit Post Office, Los Angeles 45, Calif. ATTN: WDSOT
143-144 Commander, AF Cambridge Research Center, L. G. Hanscom Field, Bedford, Mass. ATTN: CRQST-2
145-149 Commander, Air Force Special Weapons Center, Kirtland AFB, Albuquerque, N. Mex. ATTN: Tech. Info. & Intel. Div.
150-151 Director, Air University Library, Maxwell AFB, Ala.
152 Commander, Lowry Technical Training Center (TW), Lowry AFB, Denver, Colorado.
153 Commandant, School of Aviation Medicine, USAF, Randolph AFB, Tex. ATTN: Research Secretariat
154 Commander, 1009th Sp. Wpns. Squadron, HQ. USAF, Washington 25, D.C.
155-157 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio. ATTN: WCOSI
158-159 Director, USAF Project RAND, VIA: USAF Liaison Office, The RAND Corp., 1700 Main St., Santa Monica, Calif.
160 Commander, Air Defense Systems Integration Div., L. G. Hanscom Field, Bedford, Mass. ATTN: SIDE-S
161 Chief, Ballistic Missile Early Warning Project Office, 220 Church St., New York 13, N.Y. ATTN: Col. Leo V. Skinner, USAF
162 Commander, Rome Air Development Center, ARDC, Griffiss AFB, N.Y. ATTN: Documents Library, RCSSL-1
163 Commander, Air Technical Intelligence Center, USAF, Wright-Patterson AFB, Ohio. ATTN: AFCIN-4Bla, Library
164 Assistant Chief of Staff, Intelligence, HQ. USAFE, APO 633, New York, N.Y. ATTN: Directorate of Air Targets
165 Commander, Alaskan Air Command, APO 942, Seattle, Washington. ATTN: AAOTN
166 Commander-in-Chief, Pacific Air Forces, APO 953, San Francisco, Calif. ATTN: PFCIE-MB, Base Recovery

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

167 Director of Defense Research and Engineering, Washington 25, D.C. ATTN: Tech. Library
168 Director, Weapons Systems Evaluation Group, Room 1E880, The Pentagon, Washington 25, D.C.
169 Commandant, The Industrial College of The Armed Forces, Ft. McNair, Washington 25, D.C.
170 Commandant, Armed Forces Staff College, Norfolk 11, Va. ATTN: Library
171-174 Chief, Defense Atomic Support Agency, Washington 25, D.C. ATTN: Document Library
175 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex.
176 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex. ATTN: FCTG
177-181 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex. ATTN: FCWT
182 Commander, JTF-7, Arlington Hall Station, Arlington 12, Va.
183 Administrator, National Aeronautics and Space Administration, 1520 "H" St., N.W., Washington 25, D.C. ATTN: Mr. R. V. Rhode
184 Commander-in-Chief, Strategic Air Command, Offutt AFB, Neb. ATTN: OAWC
185 Commandant, US Coast Guard, 1300 E. St., N.W., Washington 25, D.C. ATTN: (OIN)
186 Commander-in-Chief, EUCOM, APO 128, New York, N.Y.
187 Commander-in-Chief, Pacific, c/o Fleet Post Office, San Francisco, Calif.
188 U.S. Documents Officer, Office of the United States National Military Representative - SHAPE, APO 55, New York, N.Y.

ATOMIC ENERGY COMMISSION ACTIVITIES

189-191 U.S. Atomic Energy Commission, Technical Library, Washington 25, D.C. ATTN: For DMA
192-193 Los Alamos Scientific Laboratory, Report Library, P.O. Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman

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194-198 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: H. J. Smyth, Jr.

199-201 University of California Lawrence Radiation Laboratory, P.O. Box 808, Livermore, Calif. ATTN: Clovis G. Craig

202 Essential Operating Records, Division of Information Services for Storage at ERC-H. ATTN: John E. Hans, Chief,

Headquarters Records and Mail Service Branch, U.S. AEC, Washington 25, D.C.

203 Weapon Data Section, Technical Information Service Extension, Oak Ridge, Tenn.

204-235 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)

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